# APPENDIX A

# SEISMIC-FORCE-RESISTING ELEMENTS IN BUILDINGS

This handbook discusses techniques for rehabilitating the seismic resistance of the following 15 common building types:

1. Wood Light Frame
2. Wood, Commercial and Industrial
3. Steel Moment Frame
4. Steel Braced Frame
5. Steel Light Frame
6. Steel Frame with Concrete Shear Walls
7. Steel with Infill Masonry Shear Walls
8. Concrete Moment Frame
9. Concrete Shear Walls
10. Concrete Frame with Infill Walls
11. Precast/Tilt-Up Concrete Walls with Lightweight Flexible Diaphragm
12. Precast Concrete Frames with Concrete Shear Walls
13. Reinforced Masonry Bearing Walls with Wood/Metal Deck Diaphragms
14. Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms
15. Unreinforced Masonry Bearing Wall Buildings

The lateral-force-resisting elements of buildings can be categorized into the following subsystems: vertical elements resisting lateral forces, diaphragms, foundations, and the connections between the subsystems. The 15 common building types considered in this report can be composed of various subsystem types. The construction of each subsystem can vary. For example, diaphragms can be constructed of timber, steel or concrete. The technique to rehabilitate a deficient subsystem and hence a deficient building depends upon the type of construction of that subsystem. The following tables present common construction of the lateral-force-resisting subsystems for the 15 common building types. These tables are provided to aid the reader in determining the types of subsystems likely to be present in a building of a given type. With an understanding of the subsystem construction and the subsystem deficiencies, the techniques presented in Chapter 3 can be investigated to determine effective ways to rehabilitate the seismic resistance of a given existing building.

TABLE A1
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 1--WOOD, LIGHT FRAME

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing. | Wood stud walls with let-in or cut-in timber bracing or plywood, straight-laid, or diagonal sheathing. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Nailing and blocking for direct shear transfer from horizontal diaphragms to shear walls or vertical bracing.<br><br>Drag struts to collect shear from horizontal diaphragms for transfer to shear walls or vertical bracing.<br><br>Bolting of shear walls and vertical bracing to concrete slabs or foundation walls.<br><br>Tension ties or hold-downs for shear walls and vertical bracing.<br><br>Nailing or bolting of vertical bracing. |

**TABLE A2**
**STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 2--WOOD, COMMERCIAL AND INDUSTRIAL**

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing. (Floor or roof decking may be 2-inch material). | Wood stud walls with let-in or cut-in timber bracing or plywood, straight-laid, or diagonal sheathing.<br><br>Knee bracing or diagonal bracing of timber columns. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Nailing and blocking for direct shear transfer from horizontal diaphragms to shear walls or vertical bracing.<br><br>Drag struts to collect shear from horizontal diaphragms for transfer to shear walls or vertical bracing.<br><br>Bolting of shear walls and vertical bracing to concrete slabs or foundation walls.<br><br>Tension ties or hold-downs for shear walls and vertical bracing.<br><br>Nailing or bolting of vertical bracing. |

TABLE A3
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 3--STEEL MOMENT FRAME

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing.<br><br>Reinforced concrete slab supported on structural steel floor framing members.<br><br>Steel decking with or without concrete fill. | Moment resisting structural steel frames. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Nailing and blocking for direct shear transfer from horizontal diaphragms to shear walls or vertical bracing.<br><br>Drag struts to collect shear from horizontal diaphragms for transfer to shear walls or vertical bracing.<br><br>Shear studs or other connections of concrete diaphragm to steel chord members.<br><br>Welding, shear studs, or other connections of steel deck diaphragms to structural steel framing.<br><br>Splice detail of steel chord members.<br><br>Beam/column connections.<br><br>Beam/column panel joint details.<br><br>Column splice details.<br><br>Column base details. |

TABLE A4
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 4--STEEL BRACED FRAME

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing.<br><br>Reinforced concrete slab supported on structural steel floor framing members.<br><br>Steel decking with or without concrete fill. | Concentric steel bracing in diagonal, X, K, or chevron configuration.<br><br>May also have moment resisting structural steel frames. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Nailing and blocking for direct shear transfer from horizontal diaphragms to shear walls or vertical bracing.<br><br>Drag struts to collect shear from horizontal diaphragms for transfer to shear walls or vertical bracing.<br><br>Shear studs or other connections of concrete diaphragm to steel chord members.<br><br>Welding, shear studs, or other connections of steel deck diaphragms to structural steel framing.<br><br>Splice detail of steel chord members.<br><br>Beam/column connections.<br><br>Beam/column panel joint details.<br><br>Column splice details.<br><br>Column base details.<br><br>Bolted or welded bracing connections. |

TABLE A5
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 5--STEEL, LIGHT FRAME

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing.<br><br>Reinforced concrete slab supported on structural steel floor framing members.<br><br>Steel decking with or without concrete fill. | Moment resisting structural steel frames.<br><br>Concentric light steel bracing in diagonal or X configuration. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Nailing and blocking for direct shear transfer from horizontal diaphragms to shear walls or vertical bracing.<br><br>Drag struts to collect shear from horizontal diaphragms for transfer to shear walls or vertical bracing.<br><br>Shear studs or other connections of concrete diaphragm to steel chord members.<br><br>Welding, shear studs, or other connections of steel deck diaphragms to structural steel framing.<br><br>Splice detail of steel chord members.<br><br>Beam/column connections.<br><br>Beam/column panel joint details.<br><br>Column splice details.<br><br>Column base details.<br><br>Bolted or welded bracing connections. |

**TABLE A6**
**STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 6--STEEL FRAME WITH CONCRETE SHEAR WALLS**

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Reinforced concrete slab supported on structural steel floor framing members.<br><br>Steel decking with or without concrete fill. | Nonmoment-resisting steel frames.<br><br>Reinforced concrete shear walls.<br><br>May also have moment resisting structural steel frames. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Shear studs or other connections of concrete diaphragm to steel chord members.<br><br>Welding, shear studs, or other connections of steel deck diaphragms to structural steel framing.<br><br>Splice detail of steel chord members.<br><br>Beam/column connections.<br><br>Beam/column panel joint details.<br><br>Column splice details.<br><br>Column base details.<br><br>Connection of concrete shear walls to floor or roof diaphragms.<br><br>Development of boundary members for concrete shear walls. |

TABLE A7
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 7--STEEL WITH INFILL MASONRY SHEAR WALLS

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing.<br><br>Reinforced concrete slab supported on structural steel floor framing members.<br><br>Steel decking with or without concrete fill. | Nonmoment-resisting steel frames.<br><br>Unreinforced masonry walls.<br><br>May also have moment resisting structural steel frames. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Nailing and blocking for direct shear transfer from horizontal diaphragms to shear walls or vertical bracing.<br><br>Drag struts to collect shear from horizontal diaphragms for transfer to shear walls or vertical bracing.<br><br>Shear studs or other connections of concrete diaphragm to steel chord members.<br><br>Welding, shear studs, or other connections of steel deck diaphragms to structural steel framing.<br><br>Splice detail of steel chord members.<br><br>Beam/column connections.<br><br>Beam/column panel joint details.<br><br>Column splice details.<br><br>Column base details.<br><br>Connection of masonry walls to steel framing. |

TABLE A8
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 8--CONCRETE MOMENT FRAME

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Reinforced concrete slab monolithic with reinforced concrete beams and girders. | Reinforced concrete frames. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Beam/column panel joint details.<br><br>Column shear reinforcement and confinement. |

TABLE A9
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 9--CONCRETE SHEAR WALLS

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Reinforced concrete slab monolithic with reinforced concrete beams and girders. | Reinforced concrete shear walls. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Connection of concrete shear walls to floor or roof diaphragms.<br><br>Development of boundary members for concrete shear walls.<br><br>Concrete diaphragm chord details. |

TABLE A10
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 10--CONCRETE FRAME WITH INFILL WALLS

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing.<br><br>Reinforced concrete slab monolithic with reinforced concrete beams and girders. | Reinforced concrete frames.<br><br>Unreinforced masonry walls. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Connection of timber floor or roof diaphragms to concrete frames.<br><br>Connection of concrete floor or roof diaphragms to concrete frames.<br><br>Connection of masonry walls to concrete frames.<br><br>Beam/column joint details.<br><br>Column shear reinforcement and confinement. |

TABLE A11
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 11--PRECAST/TILT-UP CONCRETE WALLS WITH LIGHTWEIGHT FLEXIBLE DIAPHRAGM

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing.<br><br>Reinforced concrete slab monolithic with reinforced concrete beams and girders.<br><br>Steel decking with or without concrete fill. | Precast concrete walls. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Welding, shear studs, or other connections of steel deck diaphragms to structural steel framing.<br><br>Connection of timber floor or roof diaphragms and precast walls.<br><br>Connection of concrete floor or roof diaphragms to precast walls.<br><br>Connection of steel deck floor or roof diaphragms to precast walls.<br><br>Vertical precast panel connections.<br><br>Tension ties or hold-down connections for precast panels.<br><br>Diaphragm chord details for timber, steel decking, and concrete diaphragm.<br><br>Base detail for precast panels. |

**TABLE A12**
**STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 12--PRECAST CONCRETE FRAMES WITH CONCRETE SHEAR WALLS**

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Reinforced concrete slab monolithic with reinforced concrete beams and girders. | Precast concrete frames.<br><br>Reinforced concrete shear walls. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Connection of concrete floor or roof diaphragms to precast frames or shear walls.<br><br>Development of boundary members for concrete shear walls.<br><br>Beam/column joint details.<br><br>Column shear reinforcement and confinement.<br><br>Concrete frame splice details. |

TABLE A13
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 13--REINFORCED MASONRY WALLS WITH WOOD/METAL DECK

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing.<br><br>Steel decking with or without concrete fill. | Unreinforced masonry bearing walls. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Welding, shear studs, or other connections of steel deck diaphragms to structural steel framing.<br><br>Connection of timber or steel decking floor or roof diaphragms to masonry walls.<br><br>Tension ties or hold-downs for masonry walls. |

TABLE A14
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 14--REINFORCED MASONRY WALLS WITH PRECAST CONCRETE DECK

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Precast concrete units (planks, cored slabs, tees, etc.) | Reinforced masonry walls. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Connection of precast floor or roof units to shear walls.<br><br>Connections between adjacent precast floor or roof units.<br><br>Tension ties or hold-downs for masonry walls. |

TABLE A15
STRUCTURAL ELEMENTS OF COMMON BUILDING TYPE 15--UNREINFORCED MASONRY BEARING WALLS

| Floor or Roof Diaphragm | Vertical-Resisting Elements | Foundations | Connections |
|---|---|---|---|
| Timber framing with plywood, straight-laid, or diagonal sheathing.<br><br>Reinforced concrete slab supported on structural steel floor framing members.<br><br>Reinforced concrete slab monolithic with reinforced concrete beams and girders. | Unreinforced masonry walls. | Spread footings, piles, or drilled piers. | Diagonal wire or strut bracing of ceilings from floor or roof diaphragms.<br><br>Bracing or lateral support of walls and partitions from ceilings or diaphragms.<br><br>Connection of timber or concrete floor or roof diaphragms to masonry walls.<br><br>Development of diaphragm chords in timber or concrete floor or roof diaphragms.<br><br>Tension ties or hold-downs for masonry walls. |